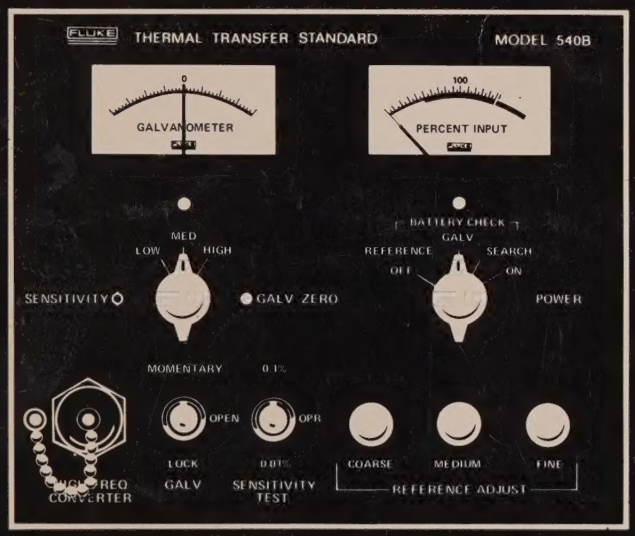
thermal transfer standard model 540B



Electronic Services - Los Angele
M16976X

student handout FLUKE

Foreword

This training course has been prepared by the Customer Service Department of the John Fluke Mfg. Co., Inc. to assist the experienced technician to understand how the instrument works, how to calibrate it and how to maintain it. Should you have any questions, comments or suggestions about this course of instruction please feel free to communicate them to the Training Department by letter or telephone.

customer service training department

john fluke mfg. co., inc.

P.O. Box 7428 • Seattle, Washington 98133
Tel: (206) 774-2409

INTRODUCTION

The 540B is a Thermal Transfer Standard that must be accompanied with either an A54-1 or A54-2 which are Voltage Plug-In Units. When combined in this fashion, the unit has 14 ranges of input from 0.5 volts to 1,000 volts. The 540B is used to either calibrate or measure AC Voltage or Current. For calibrating or measuring HF Voltage the 540B is used with an A55 plug in unit. Before going into the Theory of Operation an explanation of the operating techniques is given in order to familiarize you with the characteristics of this unit.

OPERATING TECHNIQUES

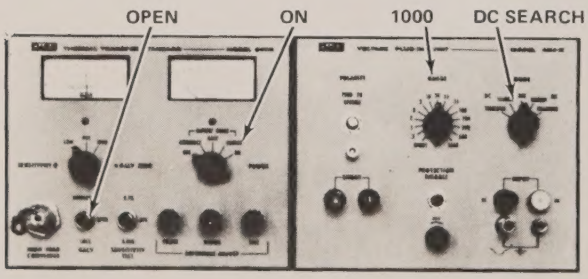
To measure or calibrate a voltage on the 540B, a technique of comparison to a known DC voltage is utilized. The Operating Techniques for the 540B are given in the Instrument Manual and are presented here in a different format so that between the both of these procedures you might be more able to understand these techniques better.

BATTERY CHECK

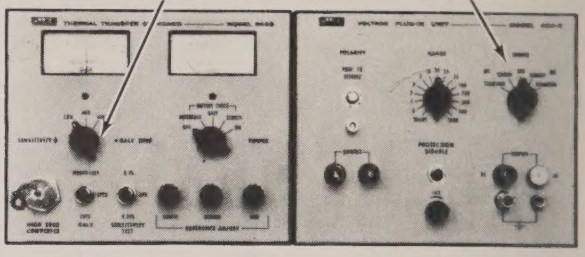
Operation

PERCENT INPUT meter must read above the lower limit of the BAT band on scale in all BAT CHECK positions.

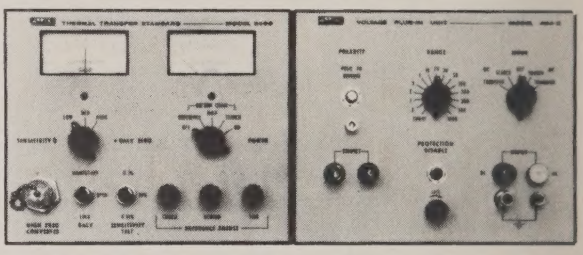
DEFLECTION SENSITIVITY



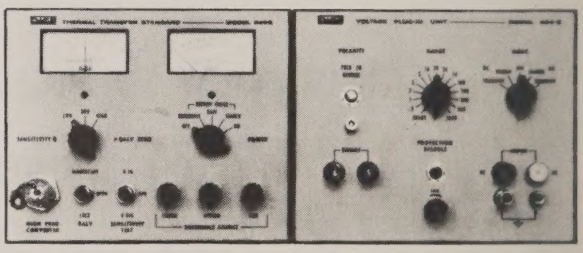
Set the RANGE switch to lower voltage ranges until an indication between 50% and 100% is obtained on the PERCENT INPUT meter.



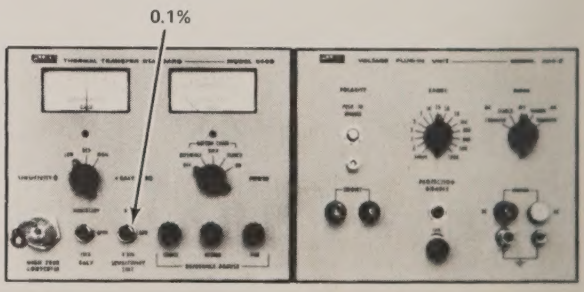
Tap the GALV switch against the spring tension to MOMENTARY just long enough to see if the GALVANOMETER needle will stay on scale. Adjust the COARSE and MEDIUM controls until a zero reading is obtained.



Adjust the GALV ZERO control for a zero reading on the GALVANOMETER.



Adjust the MEDIUM and FINE controls for a zero reading on the GALVANOMETER.



The GALVANOMETER will deflect to the right by an amount equal to a 0.1% change in input level. This deflection amount may be used to determine the deflection sensitivity (percent per unit of deflection), which in turn

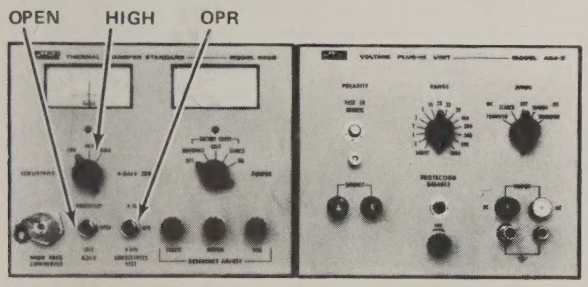
may be used to determine the percent change represented by an on scale GALVANOMETER deflection as follows:

$$\text{Deflection Sensitivity} = \frac{0.1\%}{D_t}$$

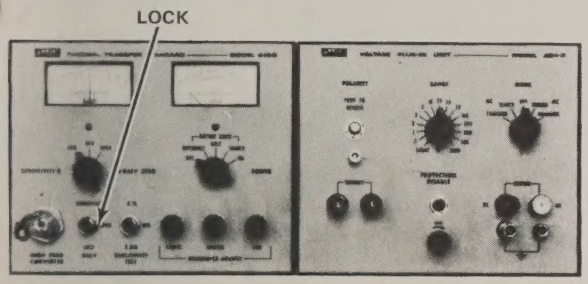
$$\%\ \text{Change} = \frac{0.1\%}{D_t} D_m$$

D_t = The number of divisions of meter deflection caused by the operation of the SENSITIVITY TEST switch.

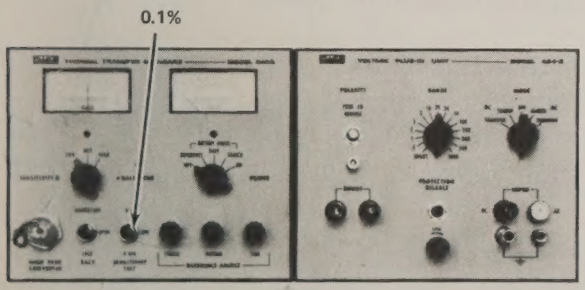
D_m = The number of divisions of meter deflection found in the transfer measurement.



Adjust the GALV ZERO control for a zero reading on the GALVANOMETER.



Adjust the FINE control for a zero reading on the GALVANOMETER.

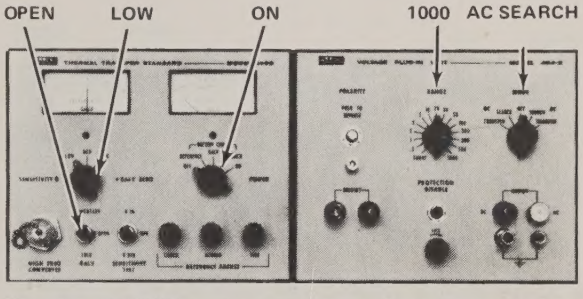


The GALVANOMETER will deflect to the right by an amount equal to a 0.01% change in input level. This deflection amount may be used to determine the deflection sensitivity (percent per unit of deflection), which in turn may be used to determine the percent change represented by an on scale GALVANOMETER deflection as follows:

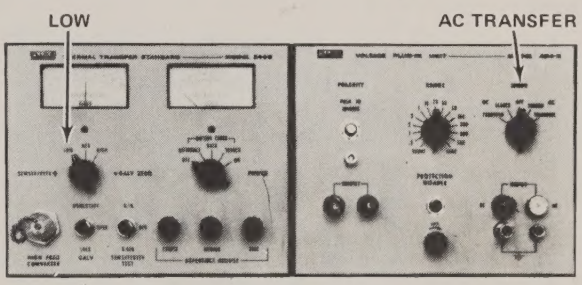
$$\text{Deflection Sensitivity} = \frac{0.01\%}{D_t}$$

$$\%\ \text{Change} = \frac{0.01\%}{D_t} D_m$$

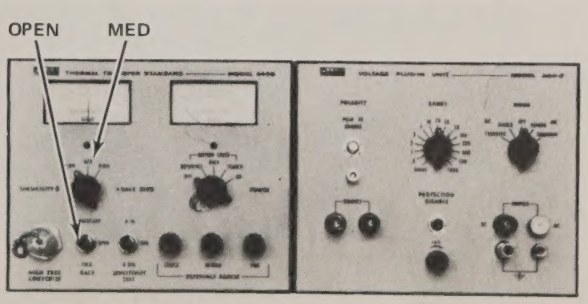
MEASURING AN UNKNOWN AC VOLTAGE



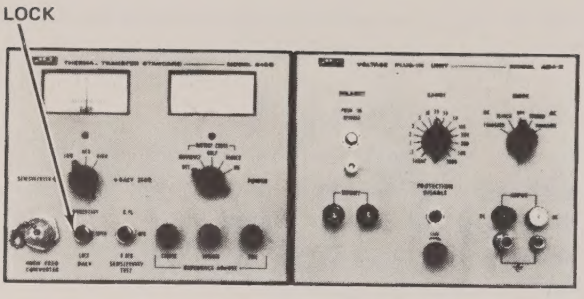
Set the RANGE switch to succeedingly lower voltage ranges until an indication between 50% and 100% is obtained on the PERCENT INPUT meter. (Better transfer resolution is obtained with readings closer to 100%.)



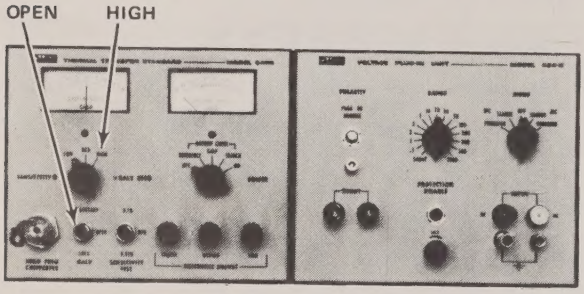
Tap the GALV switch against the spring tension to MOMENTARY just long enough to see if the GALVANOMETER needle will stay on scale. Adjust the COARSE and MEDIUM controls until a zero reading is obtained.



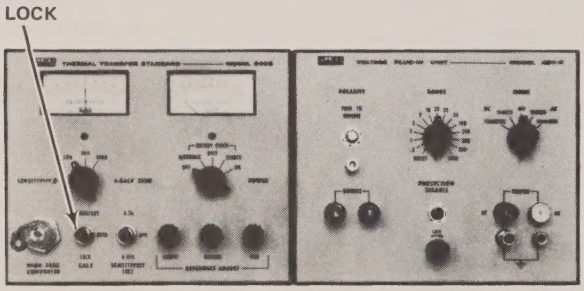
Adjust the GALV ZERO control for zero reading on the GALVANOMETER.



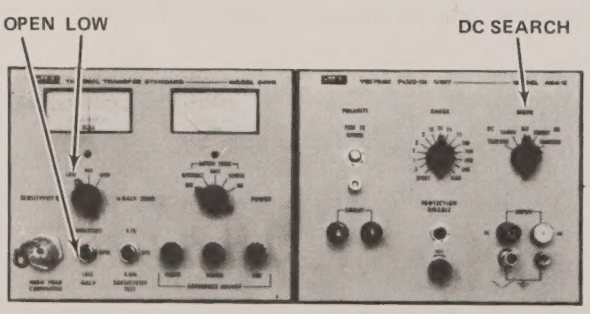
Adjust the MEDIUM and FINE controls for zero reading on the GALVANOMETER.



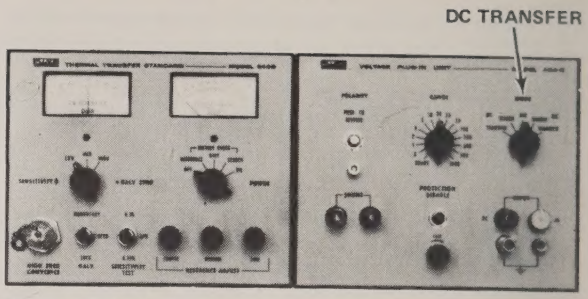
Adjust the GALV ZERO control for zero reading on the GALVANOMETER.



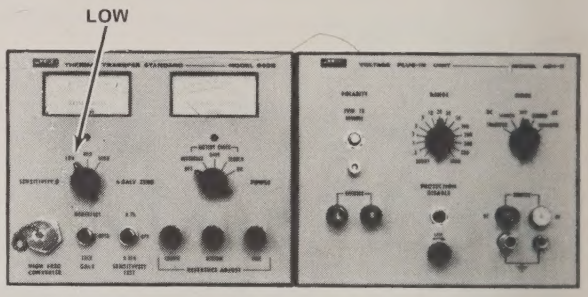
Adjust the FINE control for a zero reading on the GALVANOMETER.



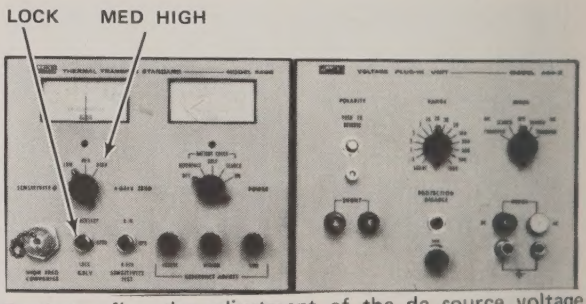
Adjust the dc source voltage until a reading is obtained on the PERCENT INPUT meter that is equal to the reading noted on the first step.



NOTE: DO NOT ADJUST THE REFERENCE ADJUST CONTROLS IN THIS MODE.



Tap the GALV switch against the spring tension to MOMENTARY just long enough to see if the GALVANOMETER needle will stay on scale. Adjust the dc source voltage until zero is obtained.



Further refine the adjustment of the dc source voltage until zero reading on the GALVANOMETER is obtained in the HIGH SENSITIVITY position.

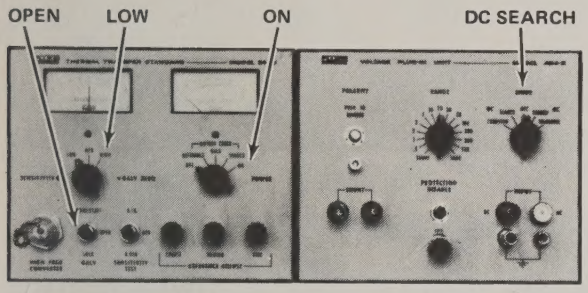
Record the exact dc source voltage.

Repeat 2nd through 11th steps at least three times or until repeatability is attained. Record the exact dc voltage.

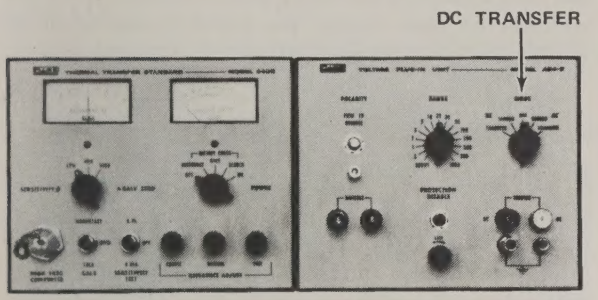
Reverse the input polarity to the thermocouple by depressing the POLARITY switch. Repeat the preceeding step.

The rms value of the unknown ac voltage is equal to the average of the two dc voltages recorded in the two preceeding steps.

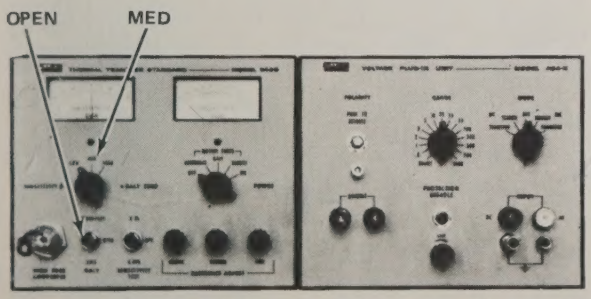
CALIBRATING AN AC VOLTAGE SOURCE



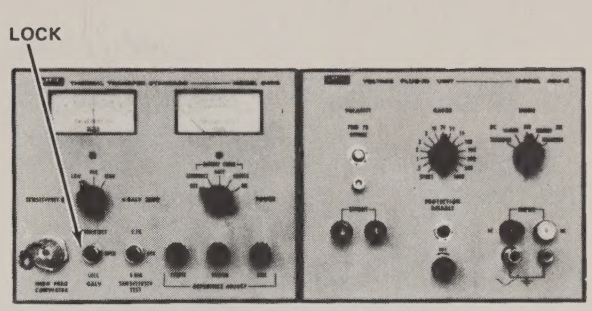
Set the RANGE switch in a position that will cause the PERCENT INPUT meter to indicate close to, but not exceed, 100% for the level to be calibrated. Adjsut the dc source voltage to the exact rms value of the ac voltage to be calibrated. (Note PERCENT INPUT meter indication.)



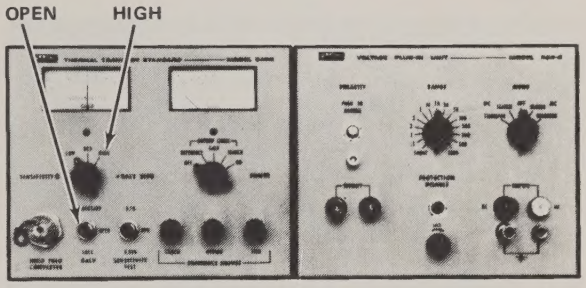
Tap the GALV switch against the spring tension to MOMENTARY just long enough to see if the GALVANOMETER needle will stay on scale. Adjust the COARSE and MEDIUM controls until a zero reading is obtained.



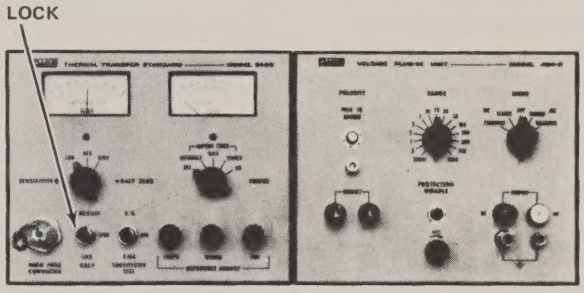
Adjust the GALV ZERO control for zero reading on the GALVANOMETER.



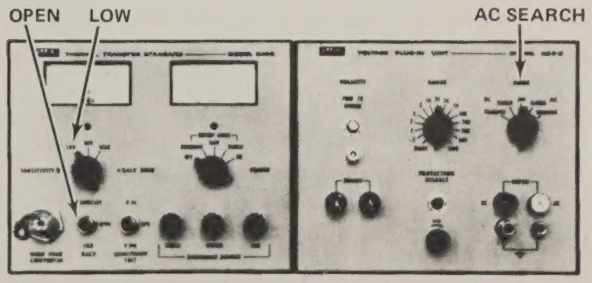
Adjust the MEDIUM and FINE controls for zero reading on the GALVANOMETER.



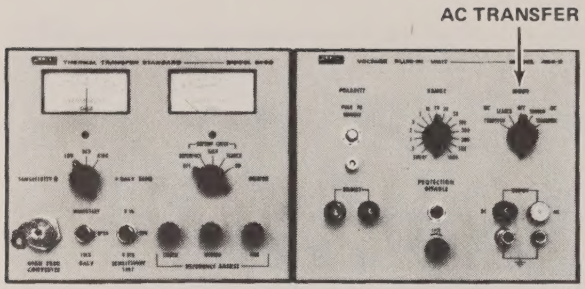
Adjust the GALV ZERO control for a zero reading on the GALVANOMETER.



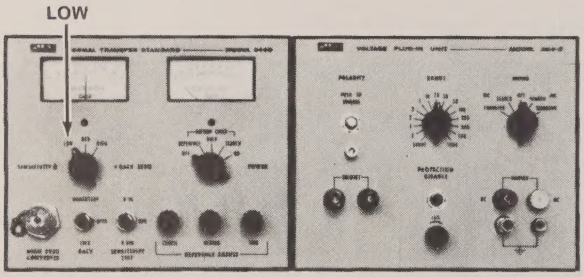
Adjust the FINE control for a zero reading on the GALVANOMETER.



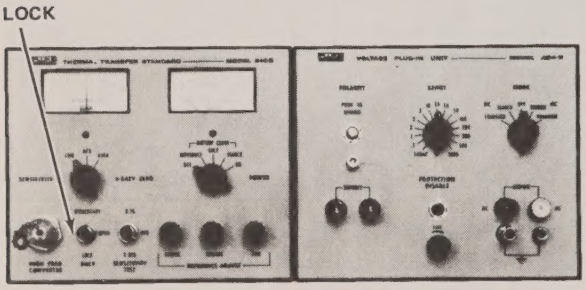
Adjust the ac level to be calibrated until a reading is obtained on the PERCENT INPUT meter that is equal to the reading obtained and noted in the 1st step.



NOTE: DO NOT ADJUST THE REFERENCE ADJUST CONTROLS IN THIS MODE.



Tap the GALV switch against the spring tension to MOMENTARY just long enough to see if the GALVANOMETER needle will stay on scale while adjusting the level of the ac to be calibrated. When an on scale reading is obtained adjust the ac level for a zero reading on the GALVANOMETER.



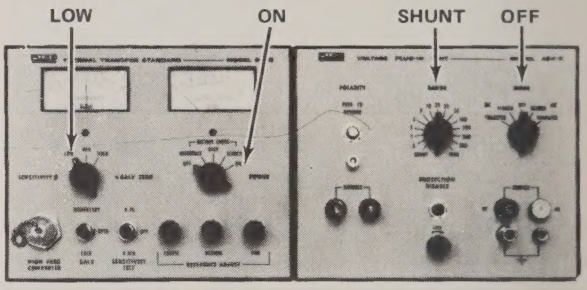
Further refine the adjustment of the ac voltage until a GALVANOMETER reading of zero is obtained in the MEDIUM and HIGH SENSITIVITY positions. Record the ac voltage source setting.

Repeat the 2nd through 10th steps at least three times or until repeatability is attained. Make note of the ac source setting.

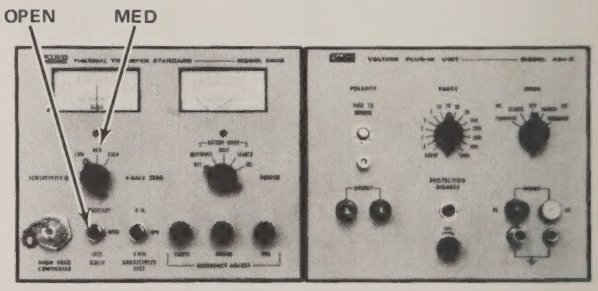
Reverse the input polarity to the thermocouple by depressing the POLARITY switch. Repeat the preceeding step.

Set the ac source voltage adjustment in the center of the two settings recorded in the two preceeding steps. The rms value of the ac voltage now equals that desired.

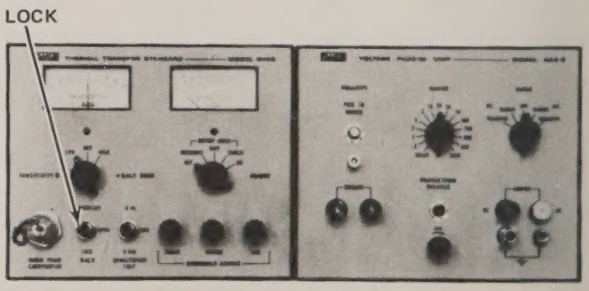
MEASURING AN UNKNOWN AC CURRENT



Connect ac source under test or, if using the A45 Transfer Switch, set the OUTPUT MODE switch to AC. Tap the GALV switch against the spring tension to MOMENTARY just long enough to see if the GALVANOMETER needle will stay on scale. Adjust the COARSE and MEDIUM REFERENCE ADJUST controls until a reading is obtained.

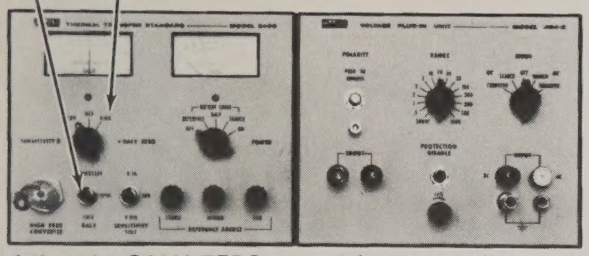


Adjust the GALV ZERO control for zero reading on the GALVANOMETER.



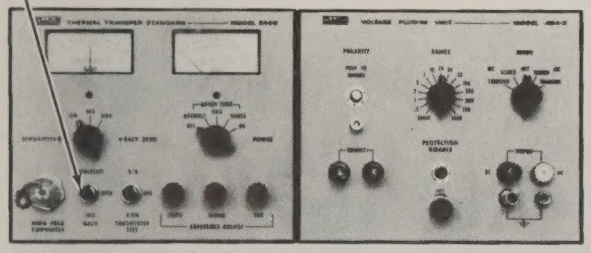
Adjust the MEDIUM and FINE controls for a zero reading on the GALVANOMETER.

OPEN HIGH



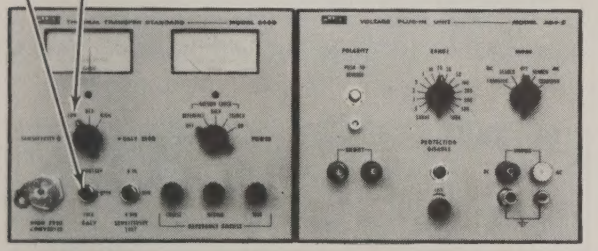
Adjust the GALV ZERO control for zero reading on the GALVANOMETER.

LOCK

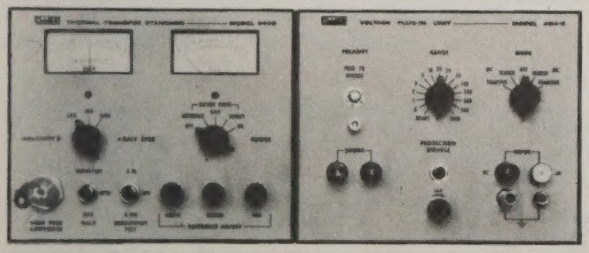


Adjust the FINE control for a zero reading on the GALVANOMETER.

OPEN LOW

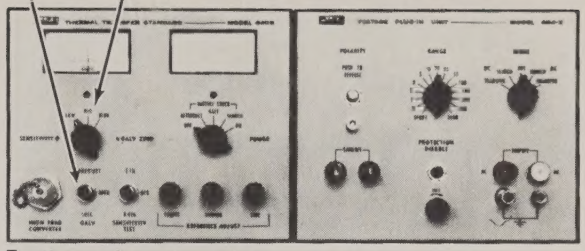


Disconnect the ac circuit under test from the current shunt and connect the dc current source, using care not to exceed the current rating of the shunt. If using the A45 Transfer Switch, set the OUTPUT MODE switch to DC.



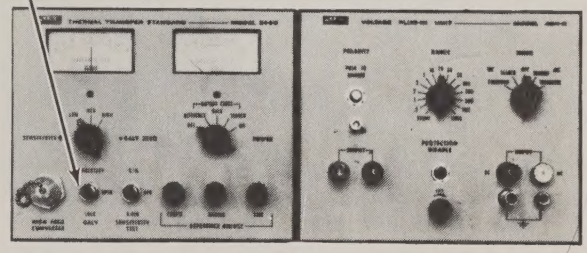
Tap the GALV switch against the spring tension to MOMENTARY just long enough to see if the GALVANOMETER needle will stay on scale while slowly increasing the dc source current until zero is reached on the GALVANOMETER. Do not adjust the REFERENCE ADJUST controls in this mode.

LOCK MED HIGH



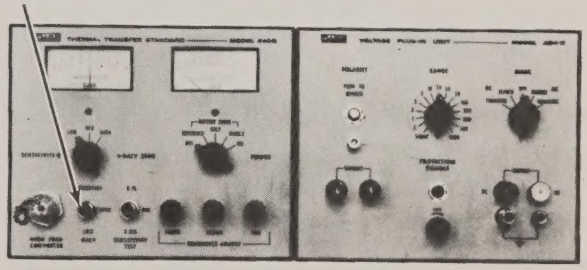
Further refine the adjustment of dc current source to maintain a zero reading on the GALVANOMETER in the MEDIUM and HIGH sensitivity positions.

OPEN



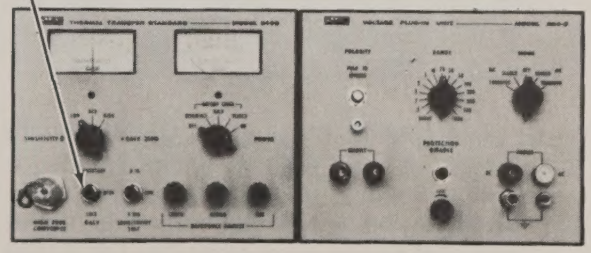
Disconnect the dc source and connect the ac current to be measured to the shunt. If using the A45 Transfer Switch, set the OUTPUT MODE switch to AC.

LOCK



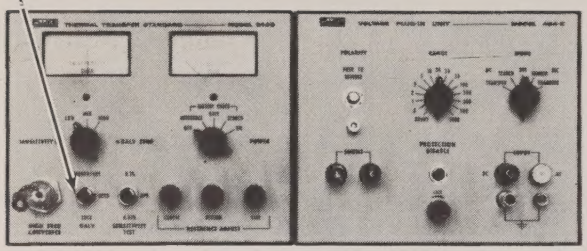
Readjust the REFERENCE ADJUST FINE control for zero on the GALVANOMETER.

OPEN



Disconnect the ac current under test and reconnect the dc source to the shunt. If using the A45 Transfer Switch, set the OUTPUT MODE switch to DC.

LOCK



Adjust the dc current source to maintain a zero reading on the GALVANOMETER. Measure and record the dc current.

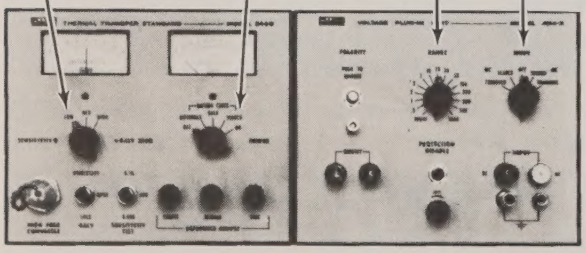
Repeat the 2nd through 12th steps at least three times or until repeatability is attained. Measure and record the dc current

Reverse the input polarity to the thermocouple by depressing the POLARITY switch. Repeat the preceeding step.

The rms value of unknown ac current is equal to the average of the two dc currents recorded in the last two preceeding steps.

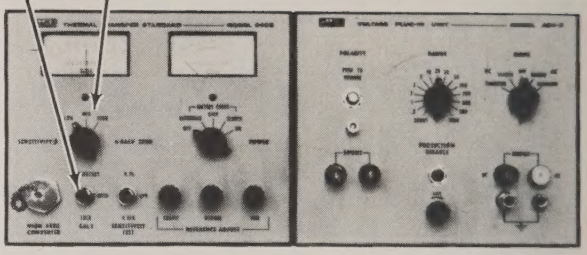
CALIBRATING AN AC CURRENT SOURCE

LOW ON SHUNT OFF



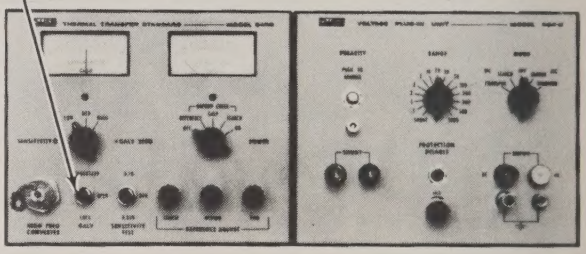
Set the OUTPUT MODE switch to DC, if using the A45 Transfer switch. Adjust the dc source until the dc current exactly equals the rms value of the ac current to be calibrated. Tap the GALV switch against the spring tension to MOMENTARY just long enough to see if the GALVANOMETER needle will stay on scale. Adjust the COARSE and MEDIUM REFERENCE ADJUST controls until a zero reading is obtained.

OPEN MED



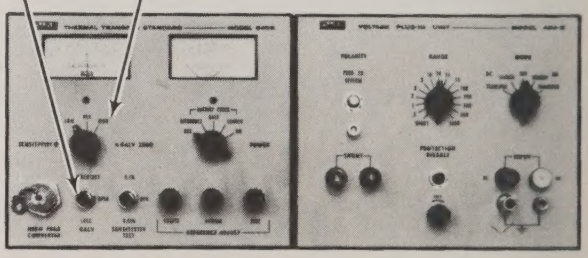
Adjust the GALV ZERO control for zero reading on the GALVANOMETER.

LOCK



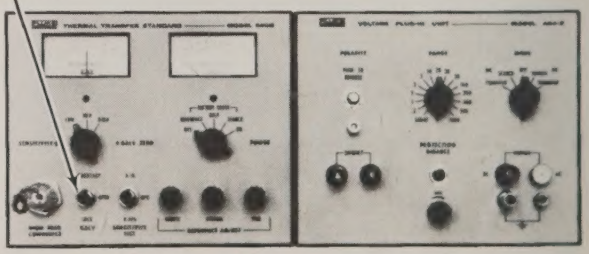
Adjust the MEDIUM and FINE controls for a zero reading on the GALVANOMETER.

OPEN HIGH



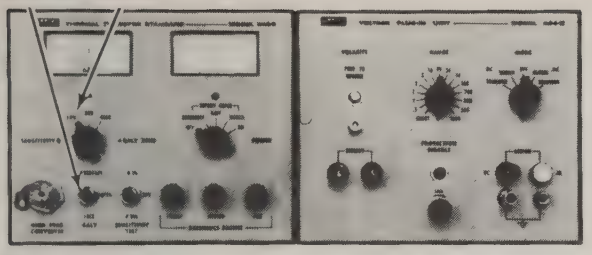
Adjust the GALV ZERO control for zero reading on the GALVANOMETER.

LOCK

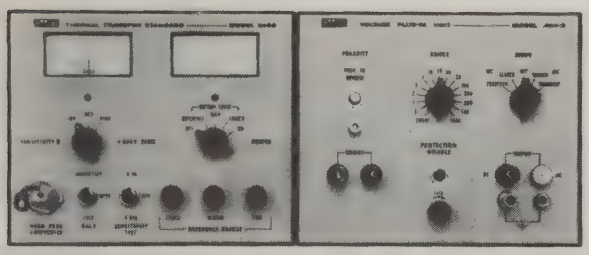


Adjust the FINE control for a zero reading on the GALVANOMETER.

OPEN LOW

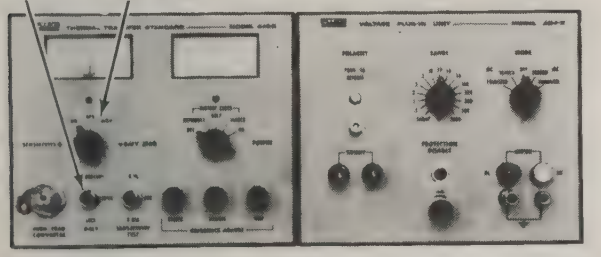


Disconnect the dc source from the shunt and connect the ac to be calibrated to it. If using the A45 Transfer Switch set the OUTPUT MODE switch to AC.



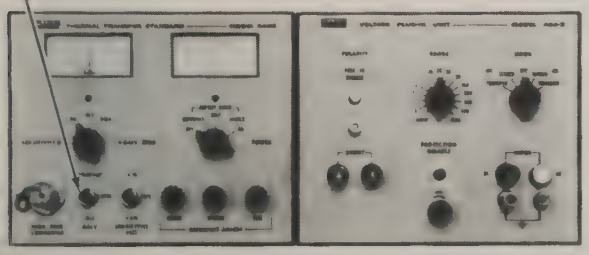
Tap the GALV switch against the spring tension to MOMENTARY just long enough to see if the GALVANOMETER needle will stay on scale while adjusting the level of the ac to be calibrated. Repeat until a zero reading is obtained. Do not adjust the REFERENCE ADJUST controls on this mode.

LOCK MED HIGH



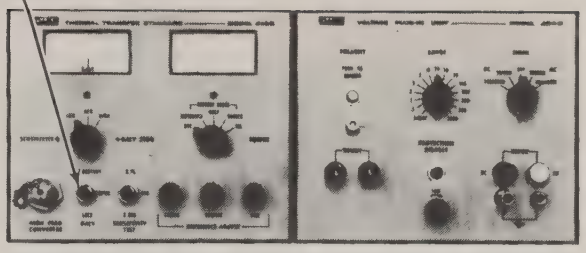
Further refine the level adjustment of the ac to be calibrated for a zero reading on the GALVANOMETER in the MEDIUM and HIGH sensitivity positions.

OPEN



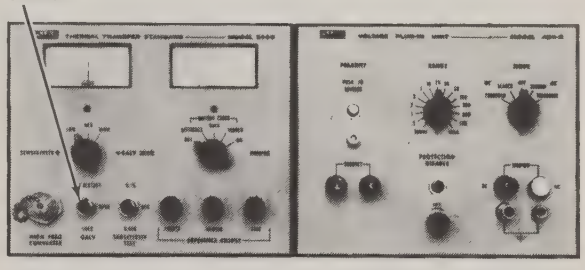
Disconnect the ac being calibrated and reconnect the dc source. If using the A45 Transfer Switch, set the OUTPUT MODE switch to DC.

LOCK



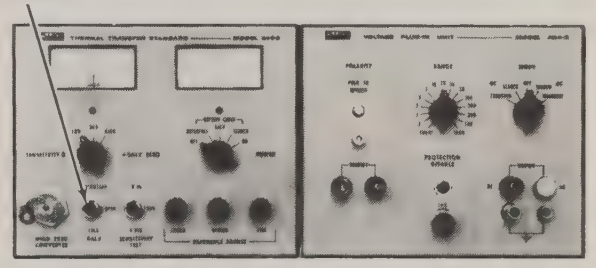
Readjust the FINE REFERENCE control for zero reading on the GALVANOMETER.

OPEN



Disconnect the dc source from the shunt input and reconnect the ac to be calibrated. If using the A45 Transfer Switch, set the OUTPUT MODE switch to AC.

LOCK



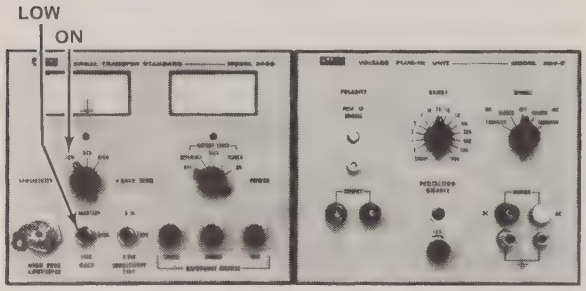
Adjust the ac current to be calibrated to maintain zero on the GALVANOMETER. Record ac current source setting.

Repeat the 2nd through 12th steps at least three times or until repeatability is attained. Record the ac current source setting.

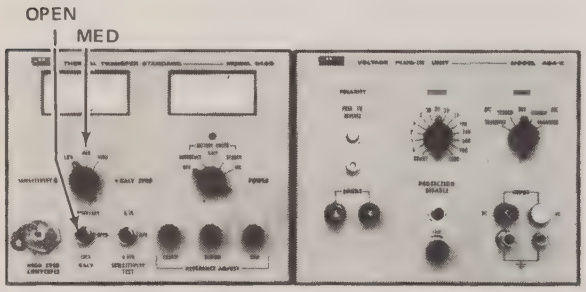
Reverse the input polarity to the thermocouple by depressing the POLARITY switch. Repeat the preceeding step.

Set the ac current source adjustment in the center of the two settings recorded in the last two preceeding steps. The rms value of the ac current now equals that desired.

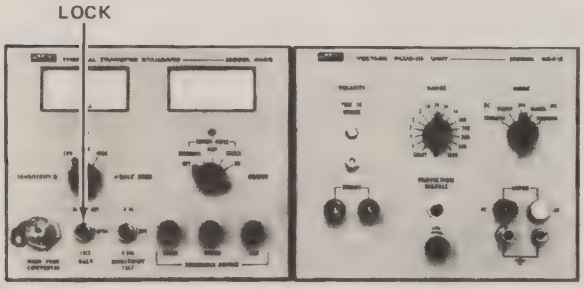
MEASURING AN UNKNOWN HF VOLTAGE



Tap the GALV switch against the spring tension to MOMENTARY just long enough to see if the GALVANOMETER needle will stay on scale while adjusting the COARSE and MEDIUM REFERENCE ADJUST controls. Repeat until a zero reading is obtained.

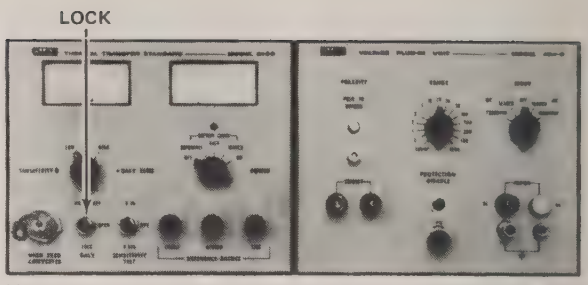


Adjust the GALV ZERO control for zero reading on the GALVANOMETER.

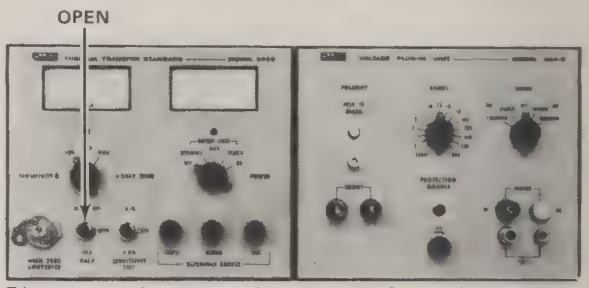


Using the MEDIUM and FINE REFERENCE ADJUST controls, zero the GALVANOMETER needle.

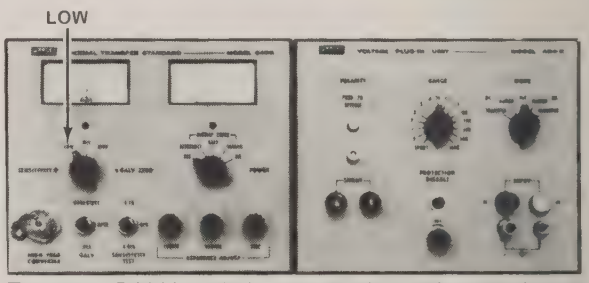
Adjust the GALV ZERO control for zero reading on the GALVANOMETER.



Using the FINE REFERENCE ADJUST controls, zero the GALVANOMETER. Do not use the REFERENCE ADJUST controls except to null the ac being measured.



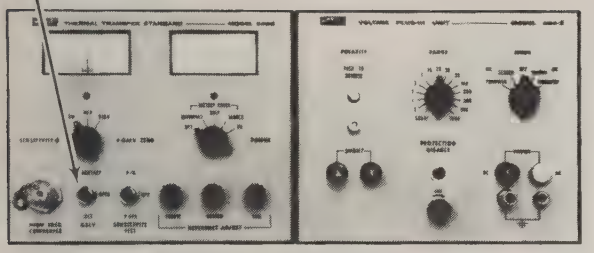
Disconnect the external converter from the ac being measured and connect it to the dc standard source, being careful not to exceed the rated value of the external converter. Adjust the dc source to the approximate rms value of the ac to be measured.



Tap the GALV switch against the spring tension to MOMENTARY just long enough to see if the GALVANOMETER needle will stay on scale, while adjusting the dc source voltage. Repeat until a zero reading is obtained.

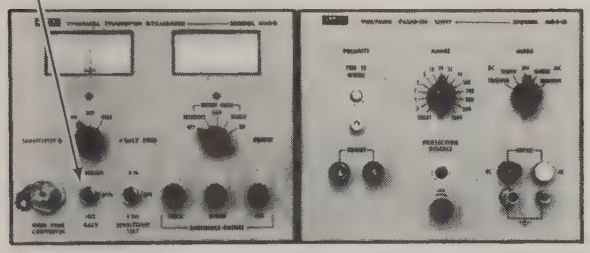
Further refine the adjustment of the dc source to maintain a zero reading on the GALVANOMETER in the MEDIUM and HIGH SENSITIVITY positions.

OPEN



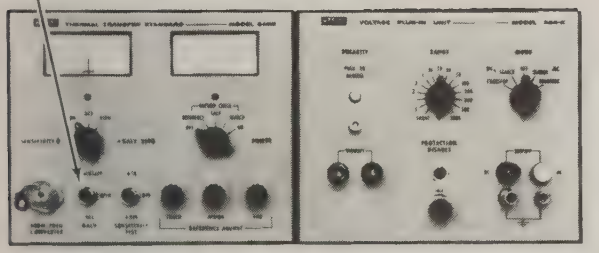
Disconnect the external converter from the dc source and reconnect it to the ac being measured.

LOCK



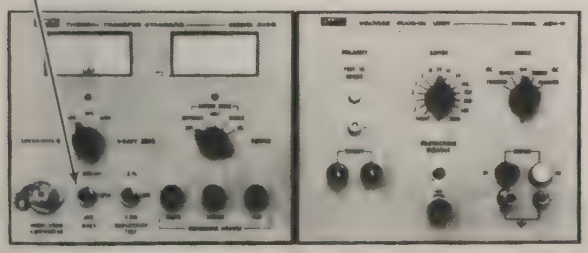
Zero the GALVANOMETER with the FINE control.

OPEN



Disconnect the external converter from the ac being measured and connect it to the dc source.

LOCK



Refine the adjustment of the dc source to obtain a zero reading on the GALVANOMETER. (note level)

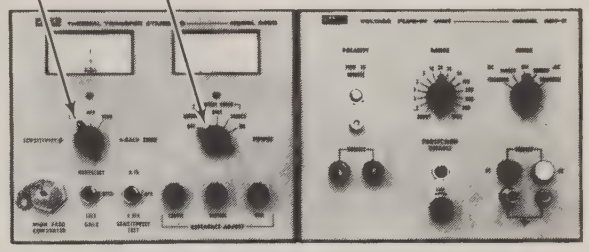
Repeat the 2nd through 12th steps at least three times or until repeatability is attained. Record the dc level.

Reverse the polarity of the dc source and repeat the preceeding step.

The rms value of the unknown ac voltage is equal to the average of the two dc voltages recorded in the last two preceeding steps.

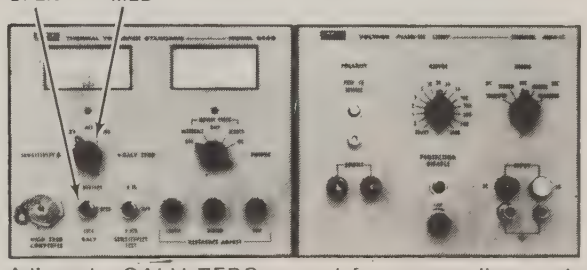
CALIBRATING AN HF VOLTAGE

LOW ON



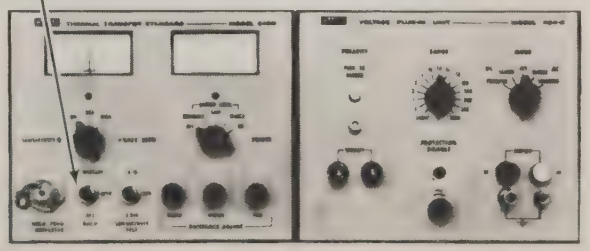
Connect the thermal converter to a calibrated dc source voltage equal to the rms value of the ac to be calibrated. Tap the GALV switch against the spring tension to MOMENTARY just long enough to see if the GALVANOMETER needle will stay on scale, while adjusting the COARSE and MEDIUM REFERENCE ADJUST controls until zero reading is obtained.

OPEN MED



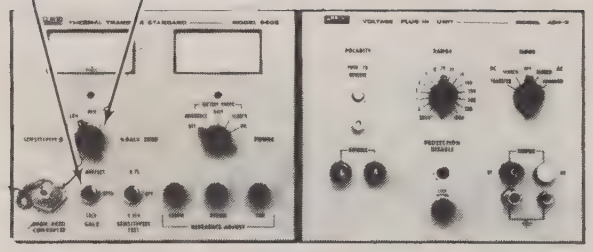
Adjust the GALV ZERO control for zero reading on the GALVANOMETER.

LOCK



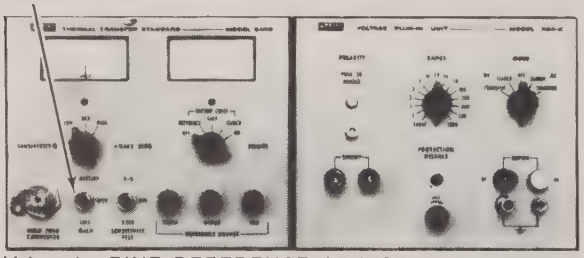
Using the MEDIUM and FINE REFERENCE ADJUST controls, zero the GALVANOMETER needle.

OPEN HIGH



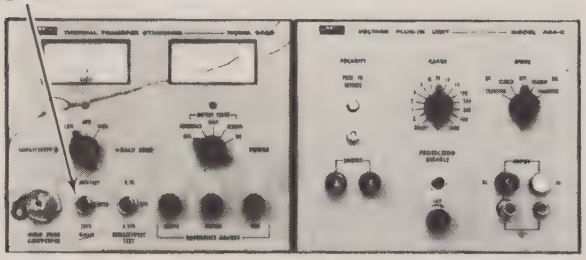
Adjust the GALV ZERO control for zero reading on the GALVANOMETER.

LOCK



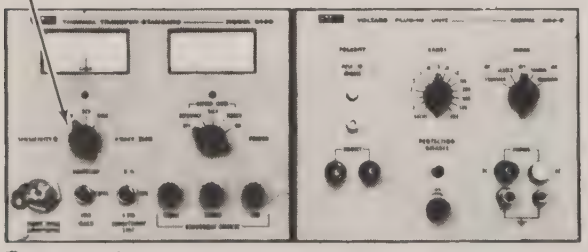
Using the FINE REFERENCE ADJUST control, zero the GALVANOMETER needle. Do not use the REFERENCE ADJUST controls except to zero the dc source voltage.

OPEN



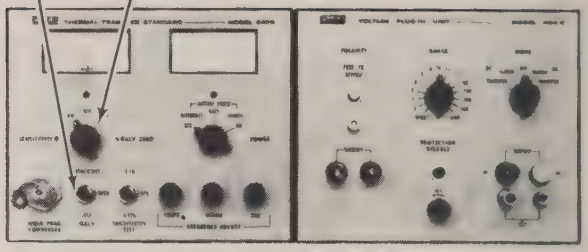
Disconnect the dc sourve voltage from the external converter and connect the ac voltage to be calibrated. Use caution not to exceed the voltage rating of the converter.

LOW



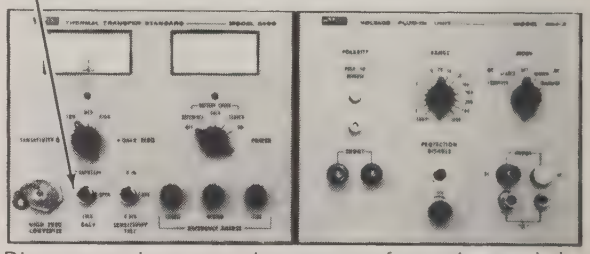
Tap the GALV switch against the spring tension to MOMENTARY just long enough to see if the GALVANOMETER needle will stay on scale, while adjusting the level of the ac voltage to be calibrated. Repeat until a zero reading is obtained.

LOCK MED, HIGH



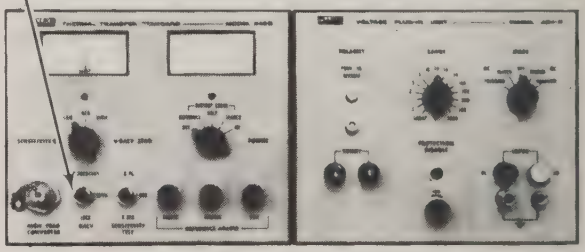
Further refine the adjustment of the ac voltage being calibrated until a zero reading on the GALVANOMETER needle is obtained in the MEDIUM and HIGH SENSITIVITY positions.

OPEN



Disconnect the external converter from the ac being calibrated and connect it to the dc standard source.

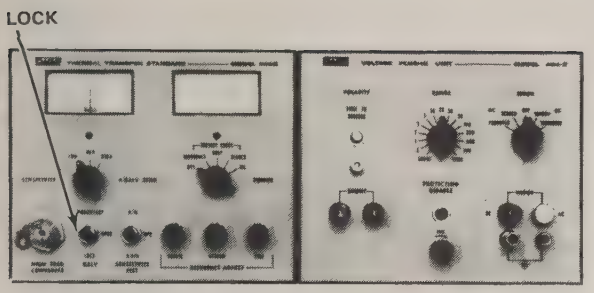
LOCK



Zero the GALVANOMETER needle with the FINE REFERENCE ADJUST control.

OPEN

Disconnect the external converter from the dc standard and connect it to the ac voltage being calibrated.



Refine the adjustment of the ac voltage being calibrated for zero reading on the GALVANOMETER.

Repeat the 2nd through 12th steps at least three times or until repeatability is attained. Record the ac voltage setting.

Reverse the polarity of the dc source and repeat the preceeding step.

Set the ac source voltage adjustment in the center of the two settings recorded in the last two preceeding steps. The rms value of the ac voltage now equals that desired.

THEORY OF OPERATION

BLOCK DIAGRAM ANALYSIS

Figure 1 is the block diagram of the model 540B. It is from this figure that the following analysis is referenced to.

With the MODE switch set in the AC SEARCH position, the incoming ac signal will be passed through the MODE switch, thru a protection relay, K801, and to two separate circuits. One labeled Search Compensated Attenuator, and the other a Transfer Compensated Attenuator. The Transfer Compensated Attenuator is a divider that, in the SEARCH position of the MODE switch is connected to another resistor, R704. These two supply the proper input impedance to the incoming signal. The Search Compensated Attenuator is a divider network that attenuates the incoming signal down to a maximum voltage of 0.5V, dependent upon the range selected. The attenuated voltage out of the Search Compensated Attenuator is then applied to the Search Amplifier, through the MODE switch, where the signal is amplified, rectified, and filtered. The resultant signal out of the amplifier is connected through another section of the MODE switch and thence to the PERCENT INPUT meter where the needle deflection is calibrated to read in percentage of input per range selected. Let's examine this further. With 0.5Vac applied to the instrument, and a range selected of 1V, and the MODE switch in the AC SEARCH position the input signal will be applied into the Search Compensated Attenuator. The 0.5V input will be divided down to 0.25Vac and applied to the Search Amplifier. The Search Amplifier will amplify, rectify, then filter the 0.25Vac into a dc voltage that is proportional to the 0.25V. This dc voltage is then applied through the MODE switch to one side (+) of the PERCENT INPUT meter. The other side of the PERCENT INPUT meter (—) is referenced to the battery supply so the meter will show what percentage the input is to the range selected.

If the input signal were to be a DC signal, the Search Amplifier is by-passed and the signal out of the Search Compensated Attenuator is fed directly to the PERCENT INPUT meter. Note that there is a Protection Amplifier in the output circuit of the Search Compensated Attenuator. This circuit functions on a preset level of either ac or dc, and will cause the input relay (K801) and the relay to the input of the thermocouple (K701) to be deactivated in the case of an overload condition. When an overload condition exists, the Protection Amplifier will also cause a relay (K301) to change it's state and as a result the PERCENT INPUT meter will indicate on it's face that the 540B is in an overload condition.

TRANSFER COMPENSATED ATTENUATOR

The Transfer Compensated Attenuator, as stated before, is an attenuator network that when the instrument is in the

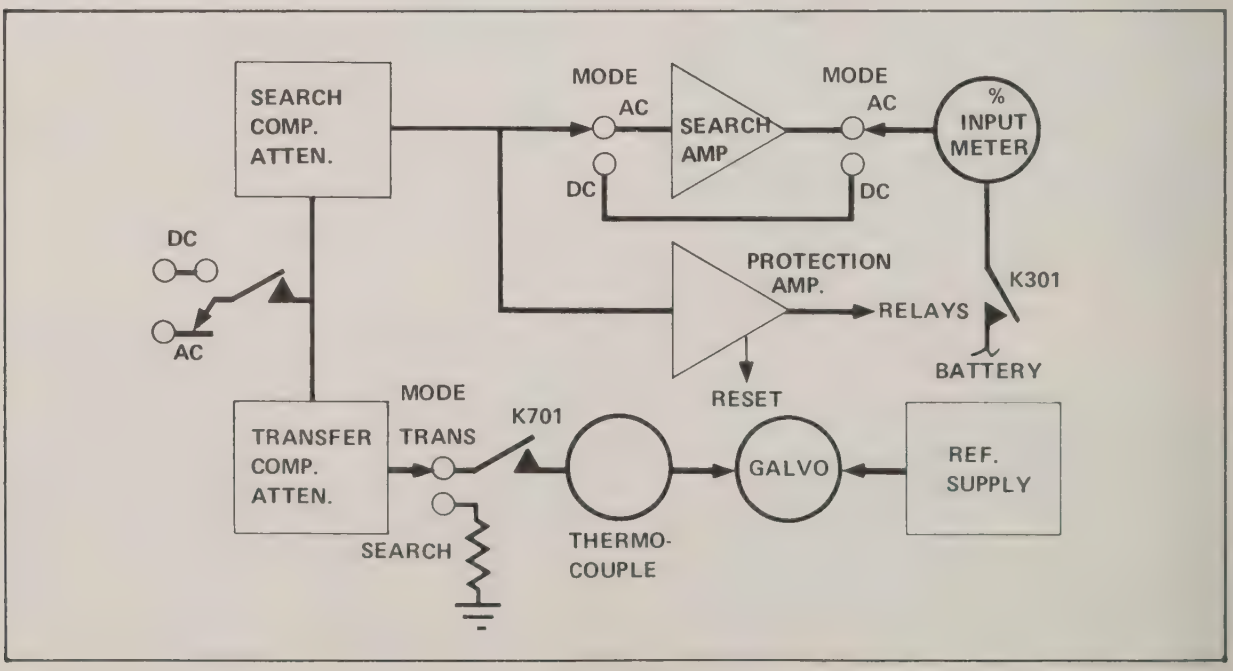


FIGURE 1

SEARCH mode, presents a constant impedance to the input signal. This Attenuator divides the input signal down to a maximum voltage of 0.5V. When in the SEARCH mode, either AC or DC, the output of the Transfer Compensated Attenuator network is applied through R704 to common. In the TRANSFER mode, either AC or DC, the output of the Attenuator network is applied through relay K701 to the Thermocouple. Relay K701 is a protection relay that is controlled by the Protection Amplifier, and will deactivate when an overload condition exists.

THERMOCOUPLE

Since a DC voltage and an AC voltage that is the same value rms wise as the DC voltage use the same amount of power, a thermocouple can be used to compare the two. The output of the Transfer Attenuator network is applied to the Thermocouple and will cause it to generate a voltage, in millivolts, on its output leg. With 0.5Vdc into the Thermocouple, the output will be 7 millivolts, and with 0.5Vac (rms) into the Thermocouple, the output will also be 7 millivolts. The output of the Thermocouple is applied to the GALVO circuit.

GALVO

Refering to Figure 2 note that one side of the Galvo circuit is fed by the Thermocouple, while the other side is fed by a balance network. Remembering that the output of the Thermocouple is approximately 7 millivolts, the Balance network can be adjusted from zero to approximately 14 millivolts. Therefore, it is possible to adjust the balance side of the Galvo circuit to the same voltage as is applied from the Thermocouple. Figure 3 is a representation of this Galvo circuit in block diagram format. Examining that block diagram, note that the Galvo circuit is comprised of

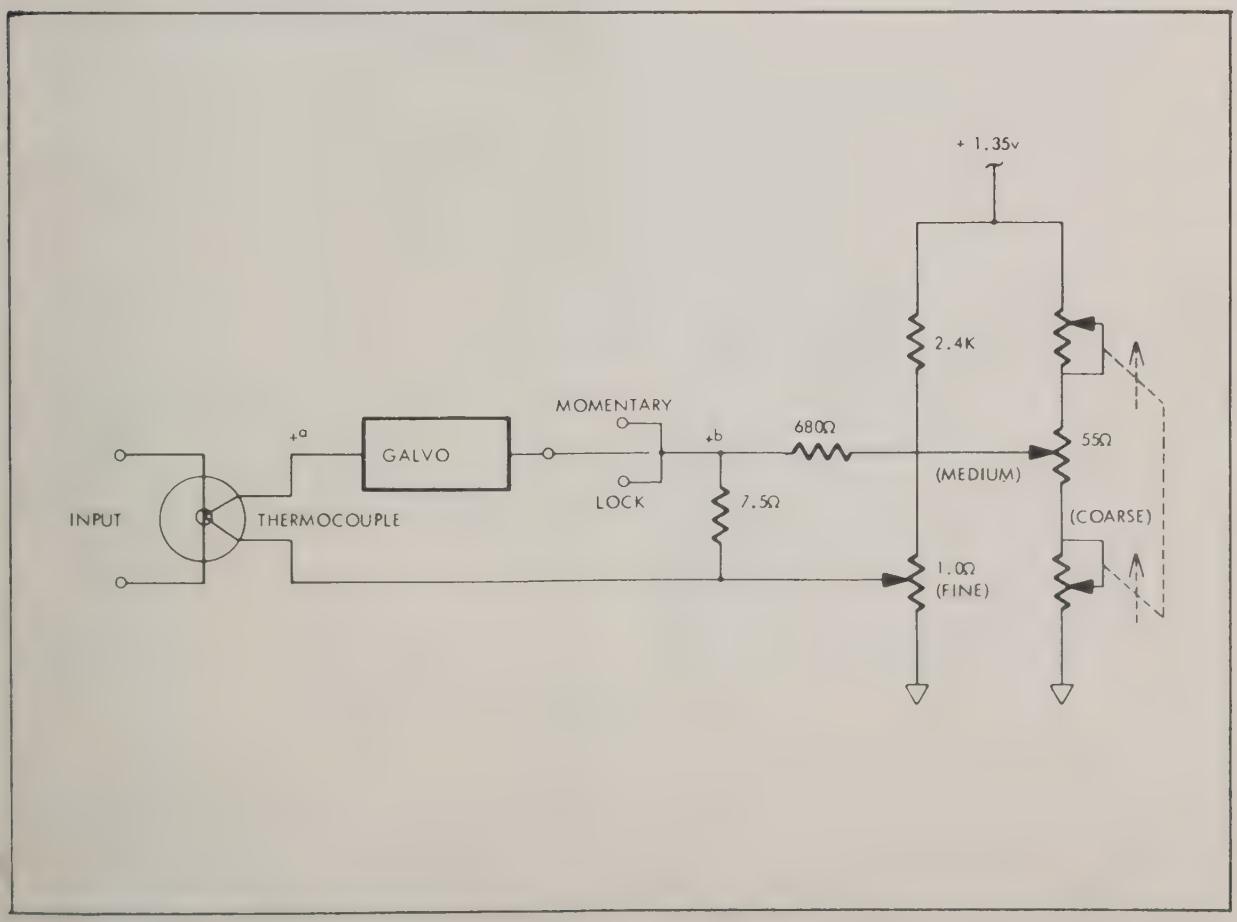


FIGURE 2

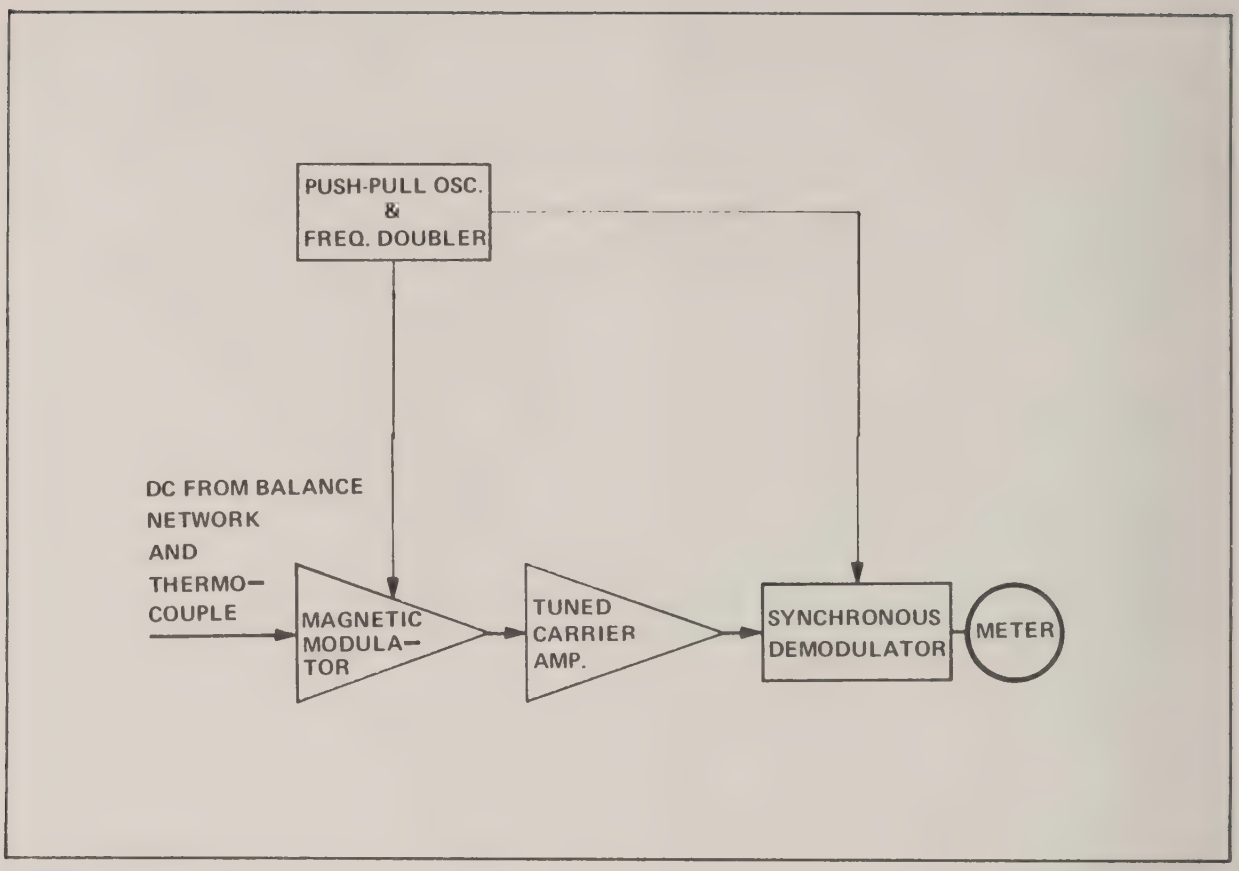


FIGURE 3

five separate circuits. The dc voltages out of the Thermocouple and Balance network are applied to a circuit called a Magnetic Modulator in such a fashion so as to cause the Modulator to react to the difference between them. The Magnetic Modulator is also fed by an Oscillator which produces a 2.5 kHz signal that is used to saturate the core of the Modulator. The output of the Magnetic Modulator is a 5 kHz signal which contians magnitude and polarity information relative to it's dc input signals. A Magnetic Modulator is used in the 540B due to the size of the signal difference between the Thermocouple and the Balance network, to give the signal some gain. The output signal from the Modulator is then fed to a Tuned Carrier Amplifier.

Tuned Carrier Amplifier

The Tuned Carrier Amplifier will amplify the incoming signal and exclude all undesireable frequencies from that signal. It in turn feeds it's output signal to the Synchronous Demodulator.

Synchronous Demodulator

The Synchronous Demodulator is fed by a synchronizing signal of 5 kHz by the Oscillator, and the signal to be are available in the Instrument Manual. The differences in demodulated from the Tuned Carrier Amplifier. This input signal is demodulated and the resultant signal is fed to a bridge network and the Galvo meter.

SCHEMATIC DIAGRAMS

This section of the Student Handout will explain the flow of the incoming signal using the Schematic Diagrams that are contained within the Instrument Manual. The schematics within this Student Handout are so assembled so as to enhance a better understanding of this instrument.

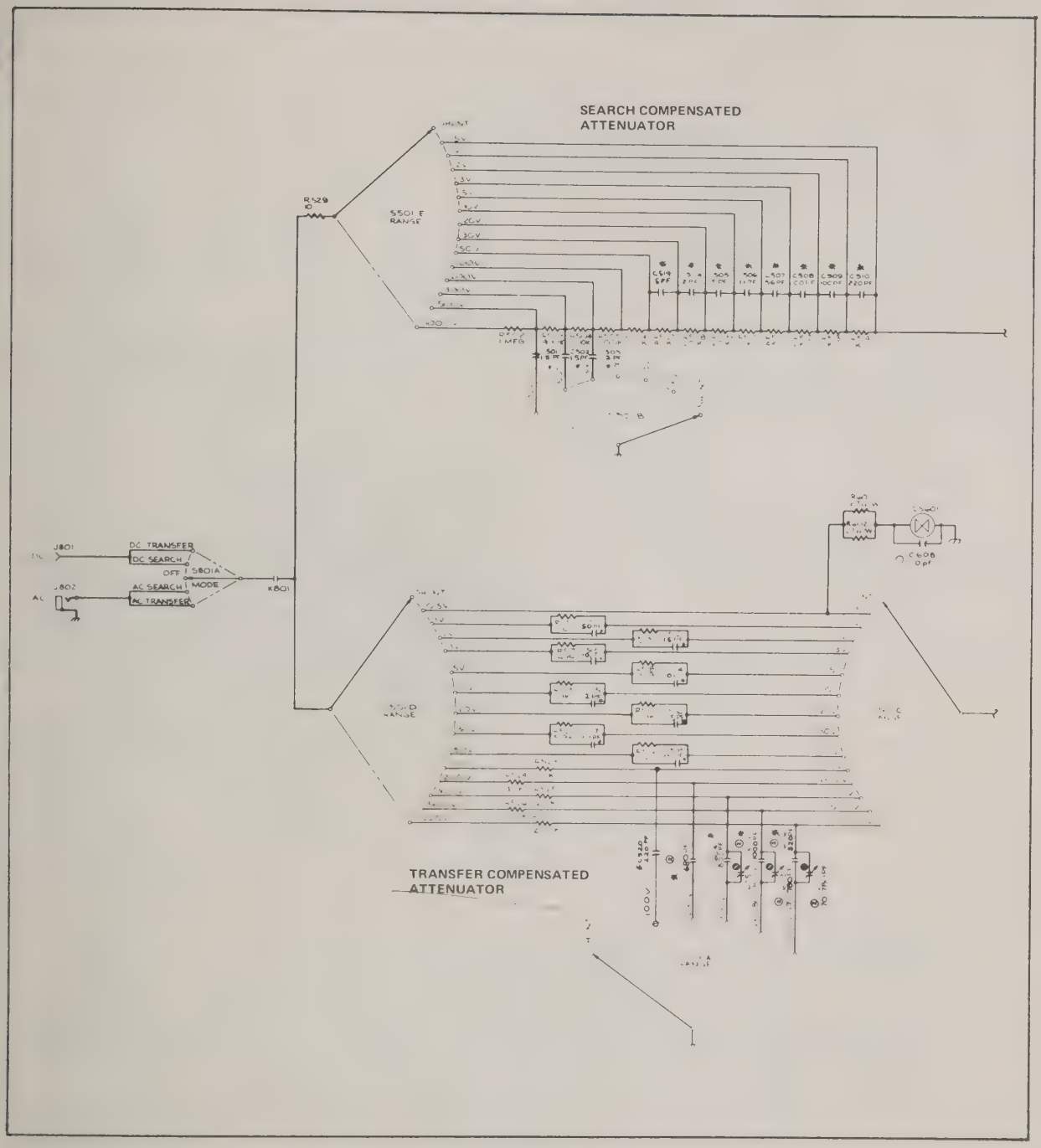


FIGURE 4

INPUT (FIGURE 4)

Figure 4 shows the input circuitry plus the Search and Transfer Compensated Attenuator networks. Both of these circuits can be found on the A54-2 schematic diagrams in the Instrument Manual. These networks attenuate the incoming signal to a maximum signal of 0.5Vac. Note that there are also several capacitors in both of these circuits, these capacitors are used for high frequency compensation to allow the wide range of signals into the instrument.

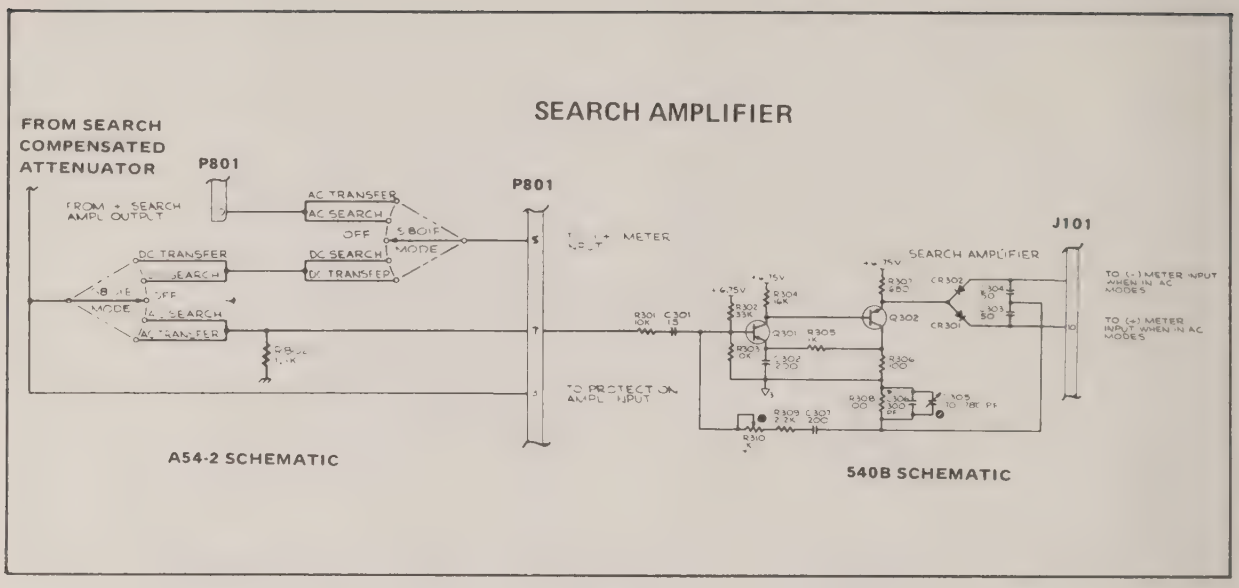


FIGURE 5

SEARCH AMPLIFIER (FIGURE 5)

The output of the Search Compensated Attenuator is applied through the MODE switch (Figure 4) which is located on the A54-2 schematic, and into the Search Amplifier, which is shown on the 540B schematic. R310 is a low frequency adjustment, while C305 is used to calibrate high frequencies. The input is amplified by transistors Q301 and Q302 after which the signal is then rectified by CR301 and CR302. Filtering is accomplished by capacitors C303 and C304.

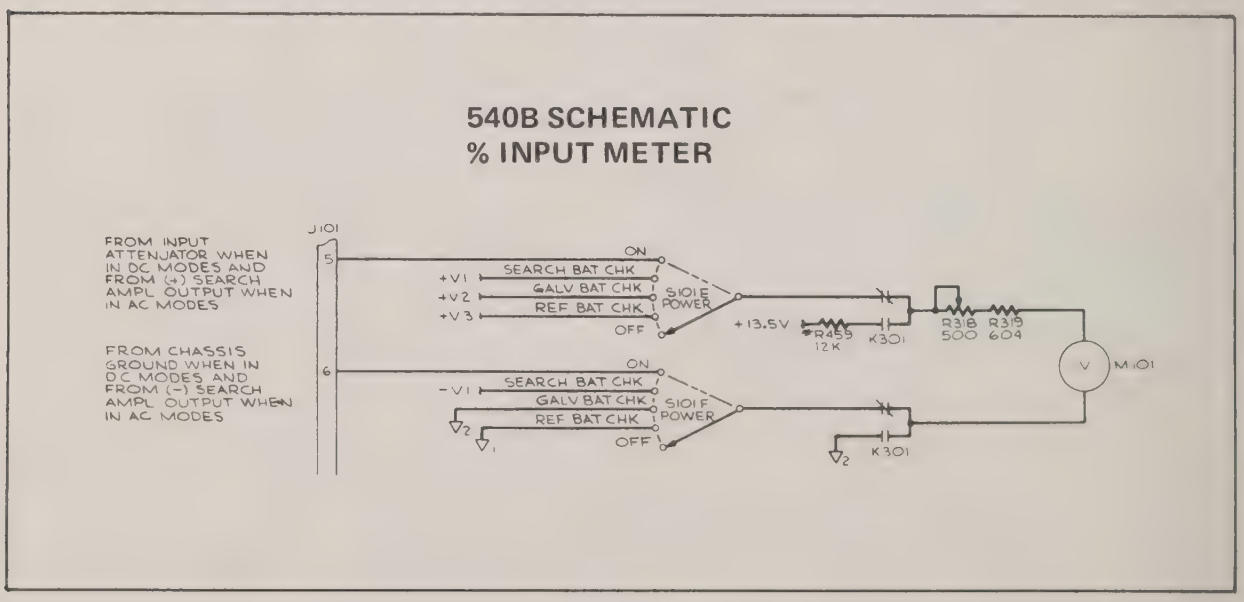


FIGURE 6

which is fed by the output of the Search Amplifier. This schematic can be found on the 540B schematic diagram in the Instrument Manual.

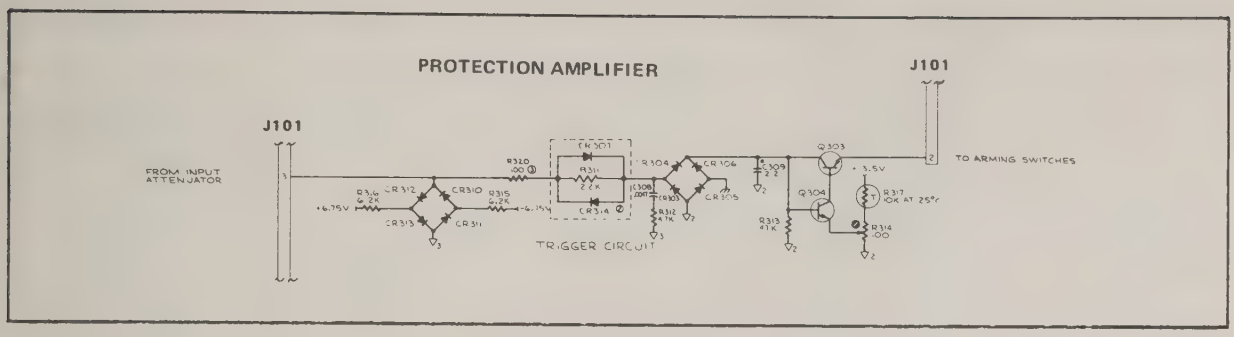


FIGURE 7

PROTECTION AMPLIFIER (FIGURE 7)

Figure 7 shows the Protection Amplifier circuitry that can also be seen on the 540B schematic of the Instrument Manual. On the input to the Protection Amplifier CR307 and CR314 present a low resistance path around R311 whenever the voltage drop across that resistor exceeds the conduction voltage of the diodes. Without these diodes, the time constant of R311 and C309 is sufficiently long to slow the operation of the Protection Amplifier enough to damage the thermocouple or other components under conditions of moderate overload, if the "speed-up" diodes were not provided.

The diode bridge network of CR301 thru CR313 is used to protect the amplifiers, Q303 and Q304, from overloads and voltage surges which might damage them. This circuit controls the state of relays K801, K701 and K301.

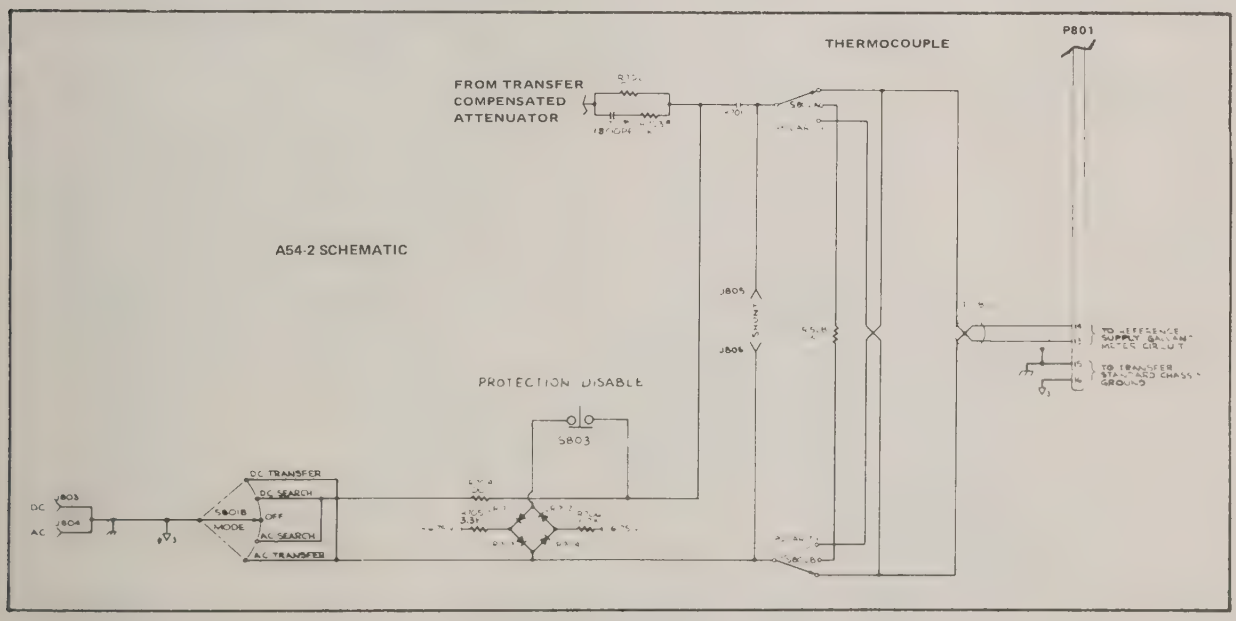


FIGURE 8

THERMOCOUPLE (FIGURE 8)

The output of the Transfer Compensated Attenuator (Figure 1) is applied to the circuit shown in Figure 8. This circuit can be found on the A54-2 schematic diagram of the Instrument Manual. In the Search position the output of the Attenuator is applied thru R702, R703, C701, down and across thru R704 and across the MODE switch to ground. When in the transfer function the output of the Attenuator will be applied through the POLARITY switch to the Thermocouple. The output of the Thermocouple is applied to the Galvo circuit.

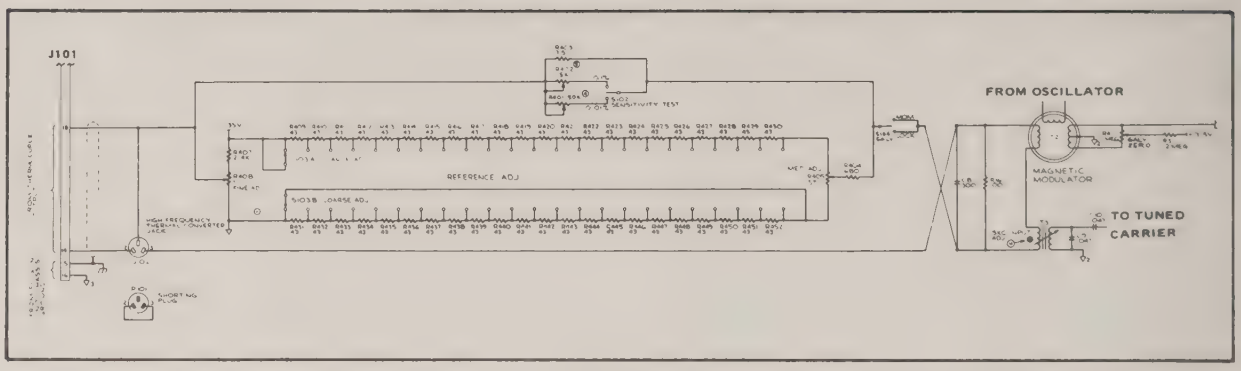


FIGURE 9

REFERENCE SUPPLY (FIGURE 9)

Figure 9 shows the input to the Magnetic Modulator from the Thermocouple on the lower line through J102, and from the balance network, the top portion of the Figure. This portion of the schematic can be found on the 540B schematic diagram in the Instrument Manual. The two inputs to the Magnetic Modulator oppose each other so the difference between them will be amplified by the Magnetic Modulator. The adjustment made to T3 is a Calibration adjustment for the signal to the Tuned Carrier Amplifier.

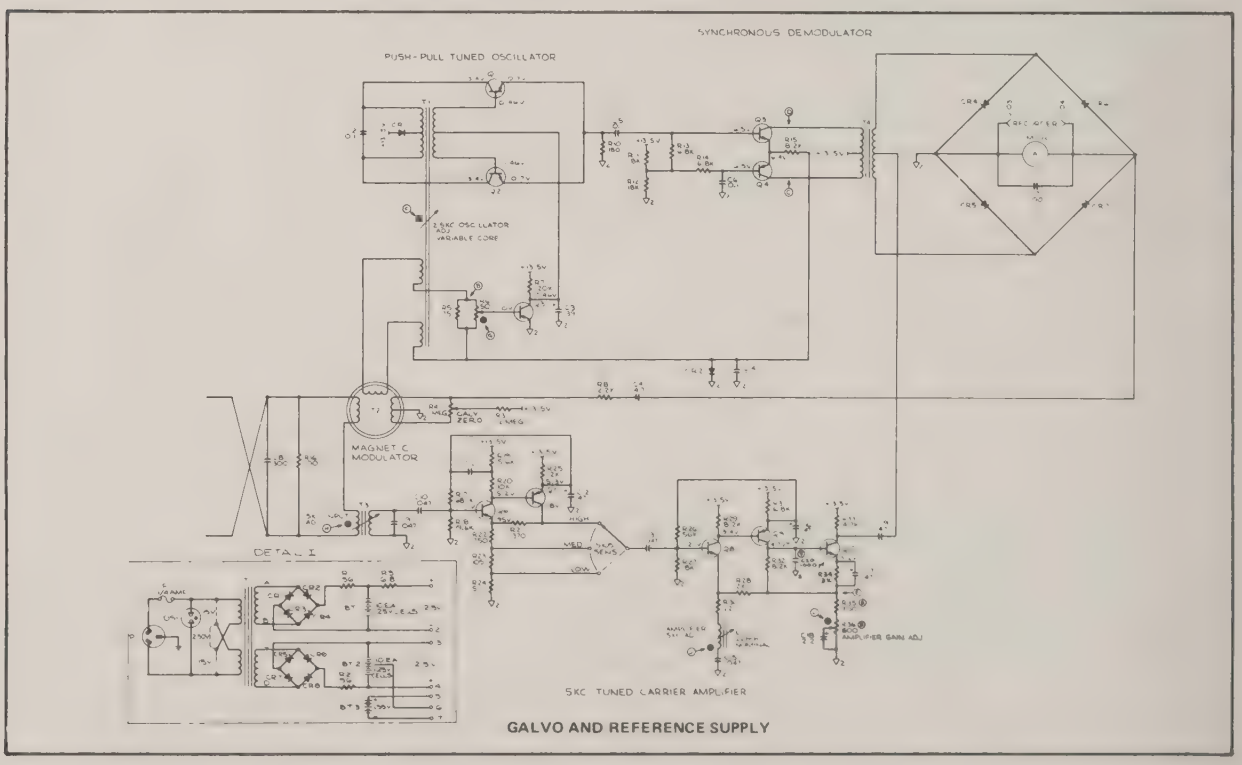


FIGURE 10

GALVO (FIGURE 10 - 13)

This figure can be found as part of the schematic diagrams of the 540B on the 540B schematic within the Instrument Manual. Contained within the Galvo circuitry is the Oscillator, Magnetic Modulator, Tuned Carrier Amplifier, Synchronous Demodulator and Push-Pull Oscillator Meter.

Figure 11 shows the Oscillator circuitry that feeds the Magnetic Modulator on the lower left portion. C2 and T1

determine that the Oscillator generates a frequency of 2.5 kHz. Transistor Q3 controls the amplitude of the Oscillator output, which will appear across R10, and is fed to the Synchronous Demodulator as a 4 kHz signal.

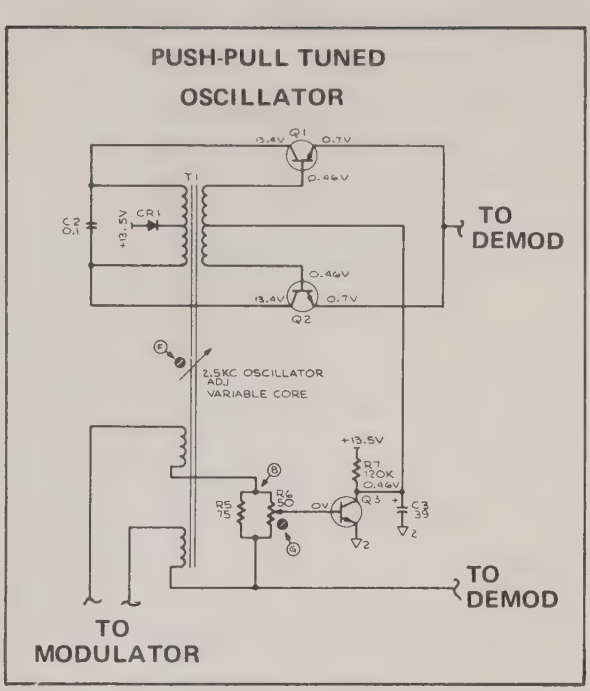
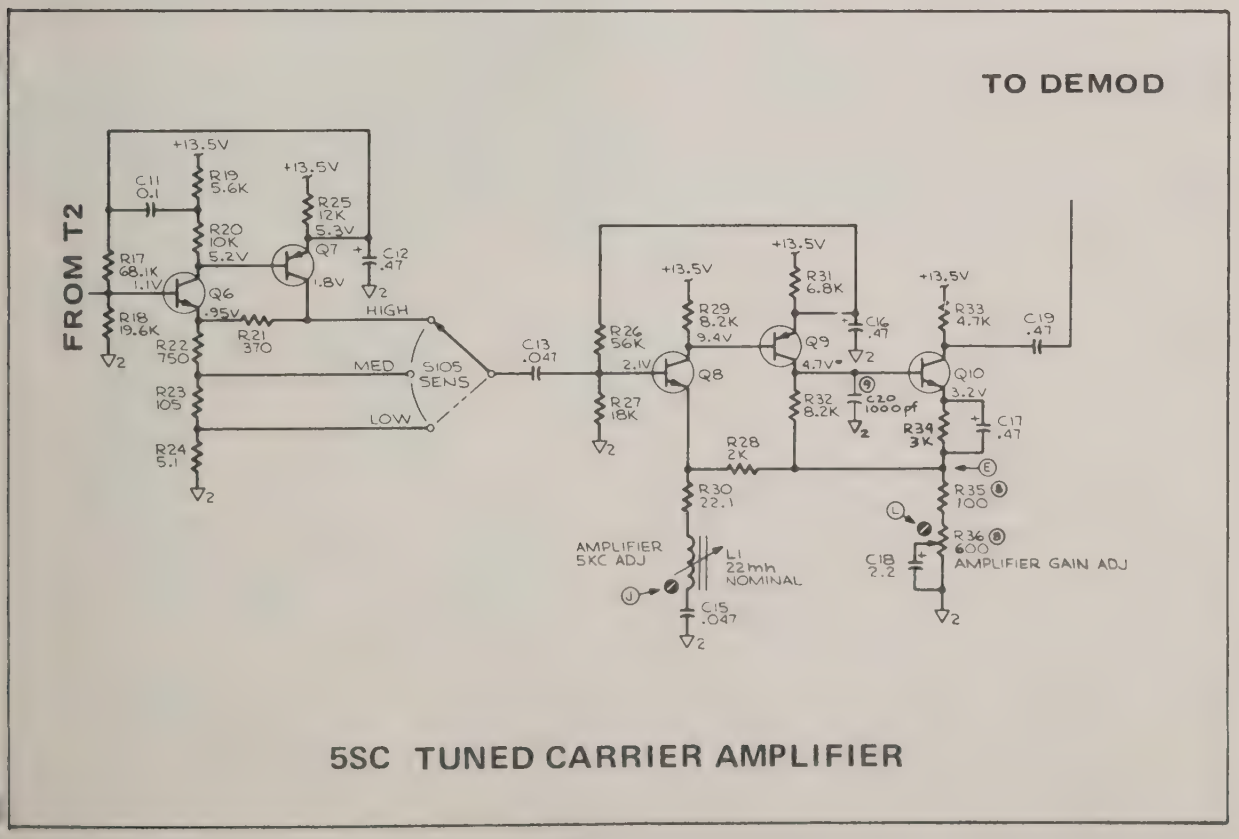


FIGURE 11

Tuned Carrier Amplifier (FIGURE 12)

The 5 kHz signal into the Amplifier is from T2 on the left portion of the Figure. Note that there are two stages of amplification by transistors Q6 thru Q9, with the gain of the first stage adjusted by the Sensitivity switch. L1 is a variable inductance that is adjusted for maximum output during calibration of the instrument. R36 is used to adjust the gain of the second stage of amplification, and is done so during the calibration of the instrument. The output of the Amplifier is through C19 to the Synchronous Demodulator.



5SC TUNED CARRIER AMPLIFIER

FIGURE 12

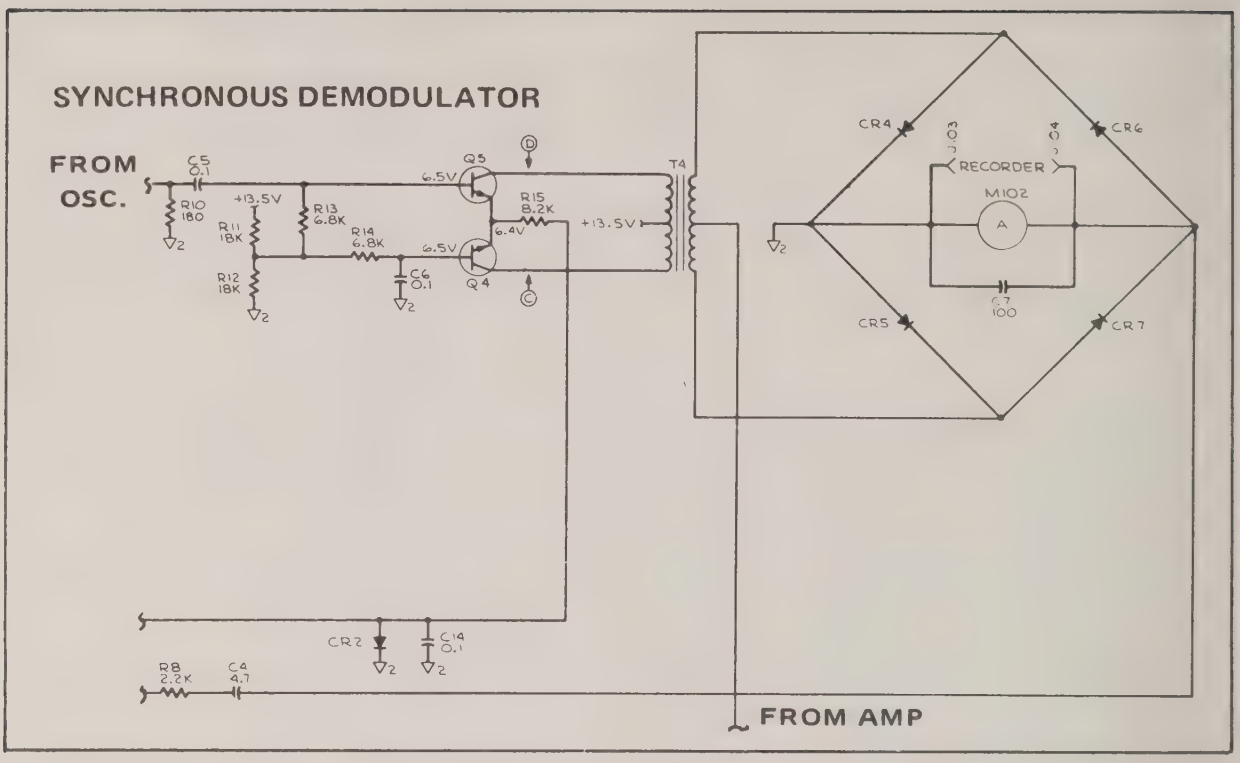
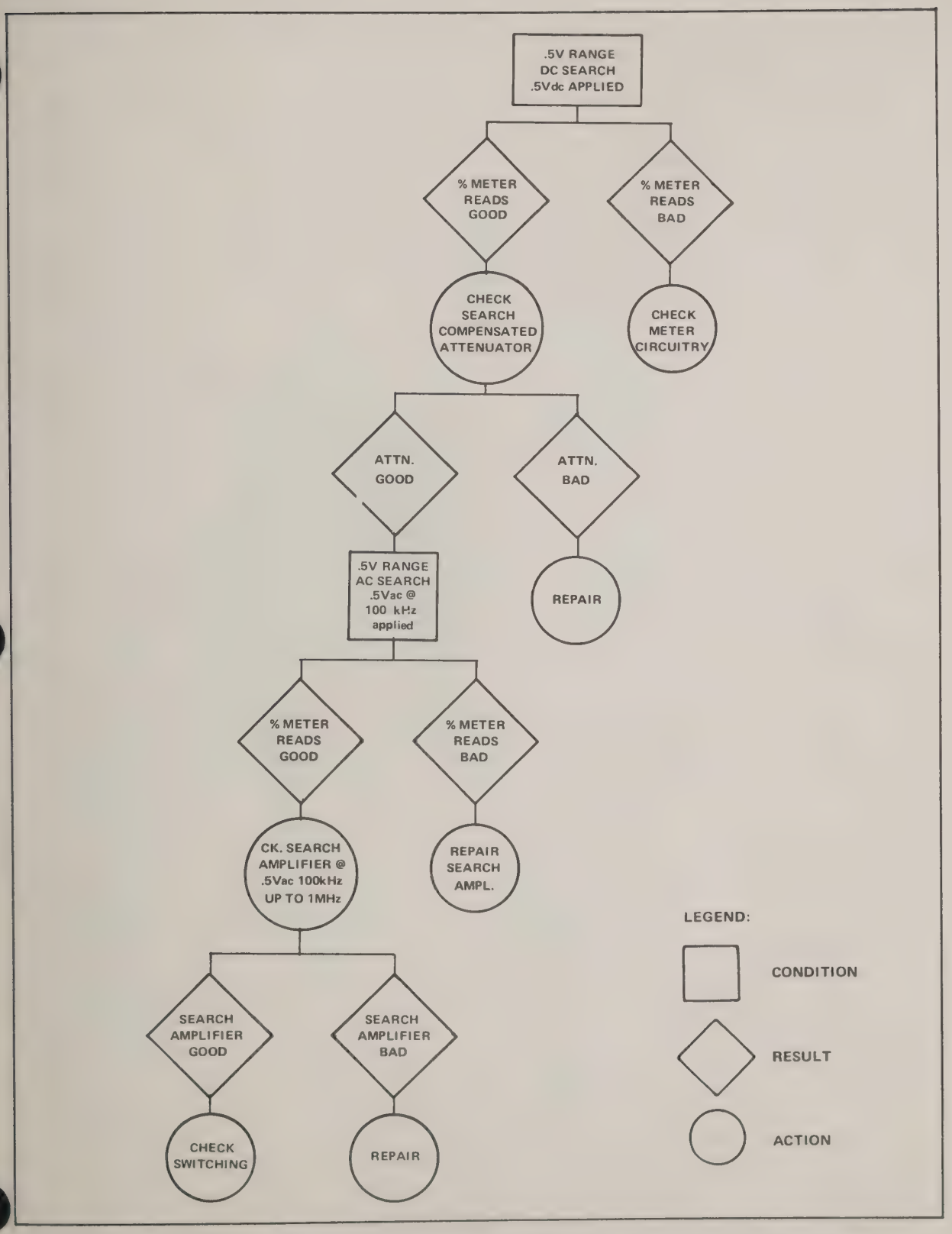


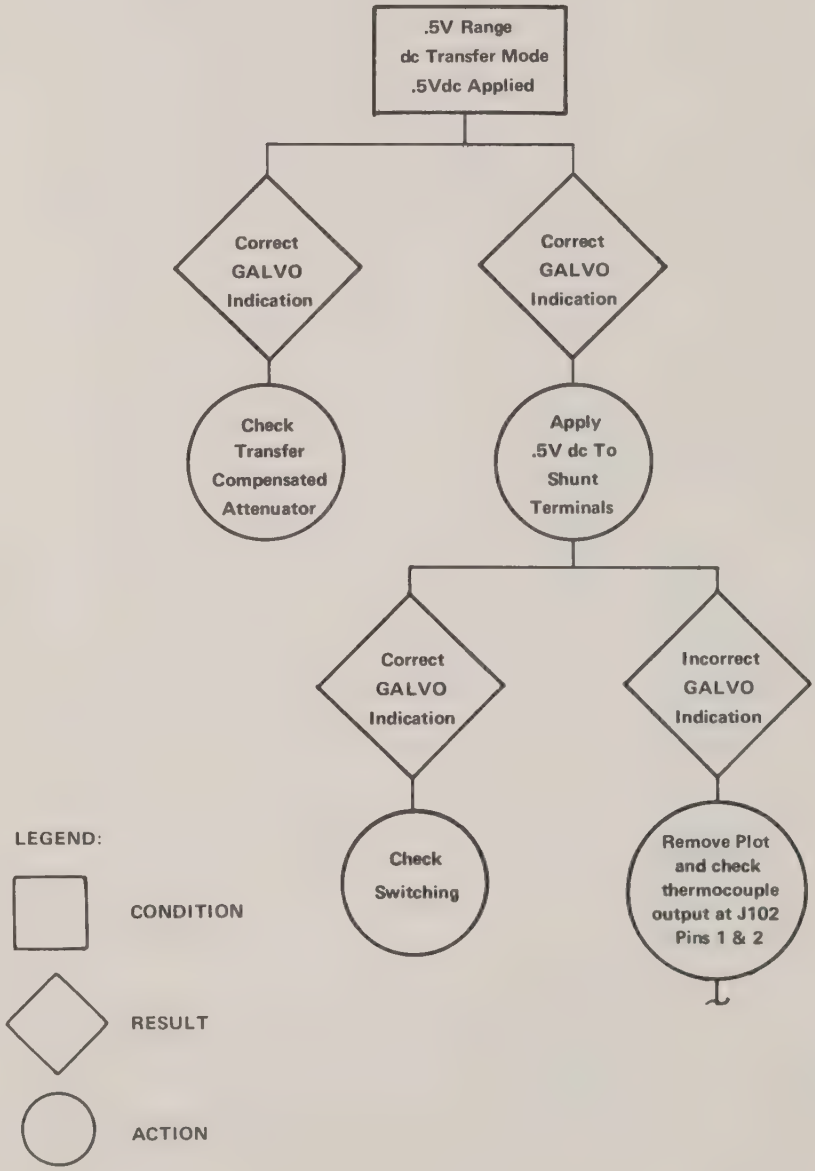
FIGURE 13

Synchronous Demodulator (FIGURE 13)

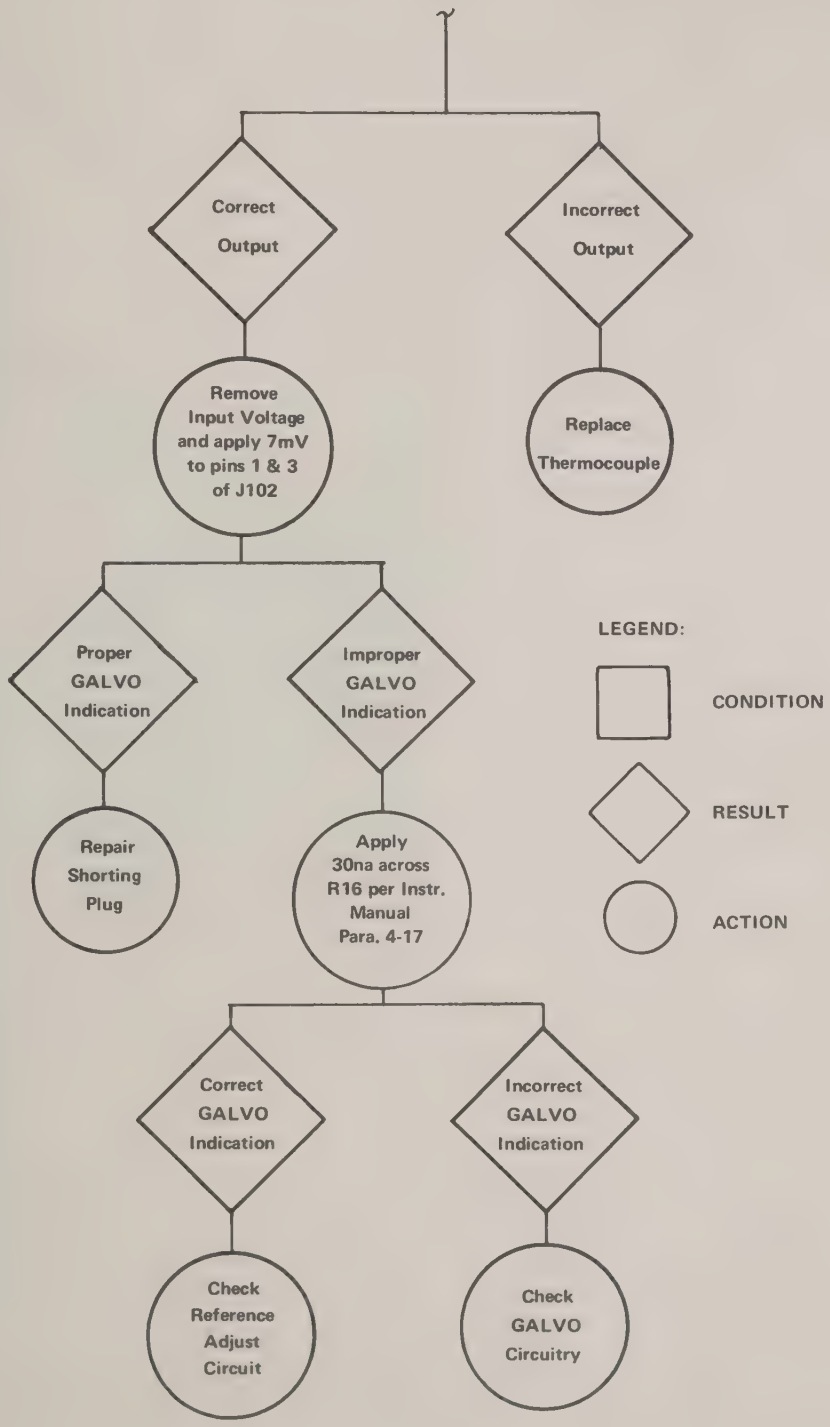
There are two signals fed to the Demodulator circuitry and they are, the 5 kHz synchronizing signal from the Oscillator on the left portion of the figure plus the output signal from the Amplifier which is fed to the secondary side of T4. That is the signal that will be demodulated and rectified by the bridge network comprised of CR4 through CR7 and the Meter.



SEARCH SECTION TROUBLESHOOTING FLOW CHART



TRANSFER SECTION TROUBLESHOOTING FLOW CHART (SHEET 1 OF 2)



TRANSFER SECTION TROUBLESHOOTING FLOW CHART (SHEET 2 OF 2)

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